Overview of Air Bearings and Design Configurations

Richard Pultar
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Introduction

Air bearings are a type of bearing that use pressurized air to create an air gap between two surfaces. As a result, the bearing surfaces do not contact which eliminates many problems associated with traditional bearings. Air bearings can provide effectively zero friction, do not require lubricants, and do not wear. They provide high stiffness and higher damping, while allowing higher speeds with smooth and practically silent operation. For these reasons, air bearings are commonly used in high precision manufacturing and testing applications. This guide will provide an overview of the types of air bearings, product configurations, typical specifications to expect from air bearings, and some of their applications and use.

Types of Bearings

Air bearings fall under one of two categories, aerodynamic or aerostatic bearings. Aerodynamic bearings require motion to generate an air film between the bearing surfaces. Therefore, when there is no motion the bearing surfaces will contact. Aerodynamic bearings may also be referred to as foil bearings or self-acting bearings.

The other category of air bearings is aerostatic bearings. These bearings require a source of pressurized air which is passed through very precise features to the bearing surfaces. Because there is a constant source of air, the air gap is maintained even when there is no motion. This guide will only discuss aerostatic bearings and their applications.

Air bearings are also classified as ‘orifice’ or ‘porous media’ bearings. Orifice bearings use a number of precisely sized and placed holes or grooves to distribute the pressurized air across the bearing surfaces. Porous bearings use specialized materials, such as porous carbon, to deliver air to the bearing surface. The porous material allows air to flow through the entire surface. Since the entire surface allows air to pass, porous bearings are less likely to fail due to scratches or other damage. They are also more resistant to damage if there is an air supply shortage.

Key Benefits

Friction

The static and dynamic coefficients of friction are extremely low and equal. This eliminates any ‘stick-slip’ issues experienced when using other types of bearings. For this reason, air bearings

are chosen when high resolution positioning requirements must be achieved. The reduction in friction also correlates to a reduction in heat, which in turn limits thermal effects on position.

Wear

Wear is greatly reduced when using air bearings. Because the bearing surfaces do not contact they only wear due to erosion. Therefore, when a clean source of air, free of debris and moisture is supplied wear is practically eliminated.

Stiffness and Load Capacity

A 6" diameter air bearing running at 60psi has a stiffness of 2,000,000 lb/in with a load of 1,000 lb. This corresponds to less than one half a millionth of an inch deflection per pound of force. As an air bearing deflects, the air gap is reduced and in turn the stiffness is increased. This high stiffness and ability to resist deflection is an important factor when choosing to use air bearings.

Product configurations

Flat Bearings (Pucks)

Flat air bearings can come in a round or rectangular form factor. They are the most common and relatively inexpensive. Many flat bearings may be used when building complex assemblies and precision machined guide ways are required. Assembly is considered easy and mounting components can take up alignment errors. The precision of flat bearings is dependent the guide ways used. Similarly, flat bearings have high stiffness and will most likely be limited by the structure and not the bearings.

Figure 1. Flat air bearing

Air Bushings

Air bushings are the least expensive and use readily available precision shafts as guide ways. Typically, bushings are mounted by pressing them into a housing with O-rings around the outer diameter of the bushing. The O-rings provide alignment, but can limit stiffness. Air bushings can be mounted with epoxy rather than O-rings to provide higher stiffness. Load capacity is limited when using one bushing, but more can be added to an assembly to increase this.

Figure 2. Air bushing

Air Bearing Slides

Preassembled air bearing slides are available in a variety of configurations. Because they are fully assembled, with air bearings integrated into their surfaces they are more expensive that the other air bearing components. Air bearing slides can be supported at the ends of the guide ways or fully supported in a dovetail or similar configuration. For the highest stiffness and load capacity a fully supported slide is best.

Figure 3. Dovetail air bearing slide

Radial Bearings

Radial bearings are similar to flat bearings, however the surface is curved. They are intended to provide rotary motion and come in a variety of profiles. Radial bearings may be either concave or convex to interface with either the outer or inner diameter or the mating surface. The curved surface can also be cut along the length or width of the bearing.

Figure 4. Radial air bearing

Spindles

BLOCK-HEAD air bearing spindles from Professional Instruments Company are a popular choice among machine builders. They combine exceptional rotational accuracy and stiffness making it possible to directly machine to optical tolerances and finishes using techniques such as diamond turning. BLOCK-HEAD air bearings, named for their 'blocky' shape, also incorporate many mounting holes and features making them easily implemented. A BLOCK-HEAD air bearing was used as the base of the Large Zenith Telescope which utilizes liquid mirror technology.

Figure 5. 4B BLOCK-HEAD air bearing spindle

Air Bearing Applications

Air bearings are used in many applications including computer disk testing, optical metrology, machine tool spindles, and roundness testing to name a few. Coordinate measuring machines (CMM) employ air bearings for their exceptional accuracy and resolution. A CMM relies on knowing the measuring probe position to a high degree of accuracy, and air bearings capability to reduce stick-slip and provide unmatched resolution are an effective solution.

Air bearings are also a common component in high speed equipment. Because of their minimal wear and smooth operation high speed machines can practically run indefinitely. High speed

equipment is also subject to thermal effects. The frictionless nature of air bearings eliminates this concern.

Ultra-precision machine tools, such as diamond turning machines, also utilize air bearing technology. The unmatched accuracy and resolution of air bearings are a necessary component of these machines and allow parts to be directly machined to optical quality.

Using Air Bearings

Mounting Flat Bearings

Flat air bearings need to be parallel to within a few microns of the guide surface. For this reason, a ball stud is used to mount the bearing. Rather than rigidly mounting the bearing, the ball stud fits into a spherical socket accommodating misalignment. Figure 6 to the right shows a possible configuration using a ball stud.

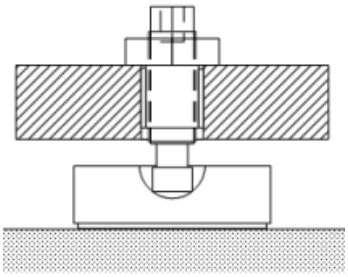

Figure 6. Mounting of flat air bearing with ball stud

Mounting Air Bushings

Air bushings are typically pressed into a pillow block with O-rings on the bushings outer diameter. To do so, the O-rings are first wet with alcohol and the bearing is inserted into the pillow block. After supplying air to the bearing, a clean precision shaft can then be inserted into the bushing. Figure 7 below depicts this process.

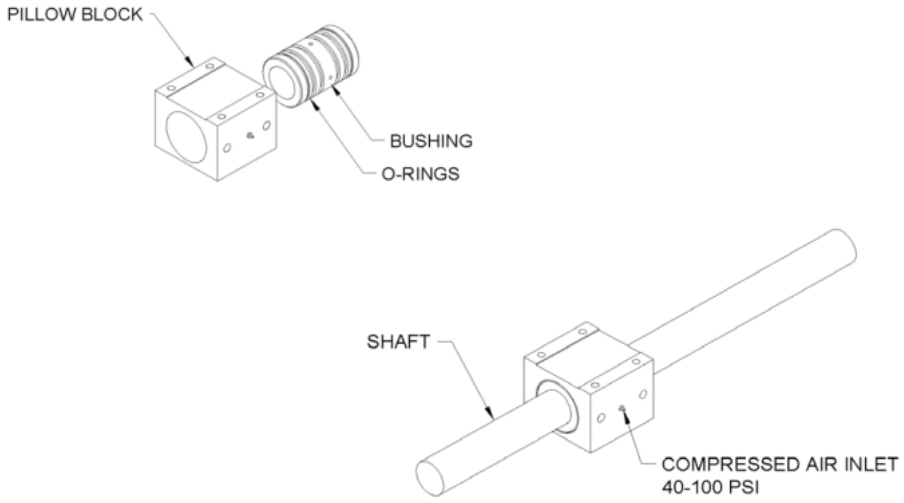

Figure 7. Mounting of air bushing

Typical Configurations of Air Bearings

The figures below depict some of the typical configurations of air bearings.

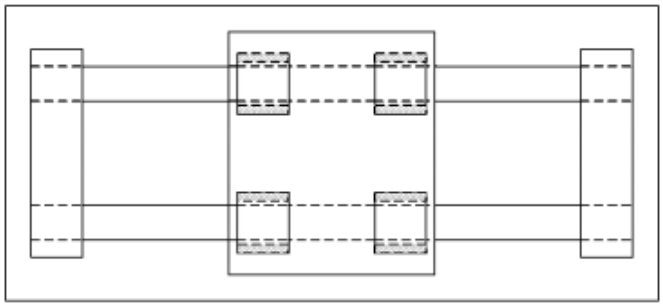

Figure 8. Four air bushing used to create a linear slide

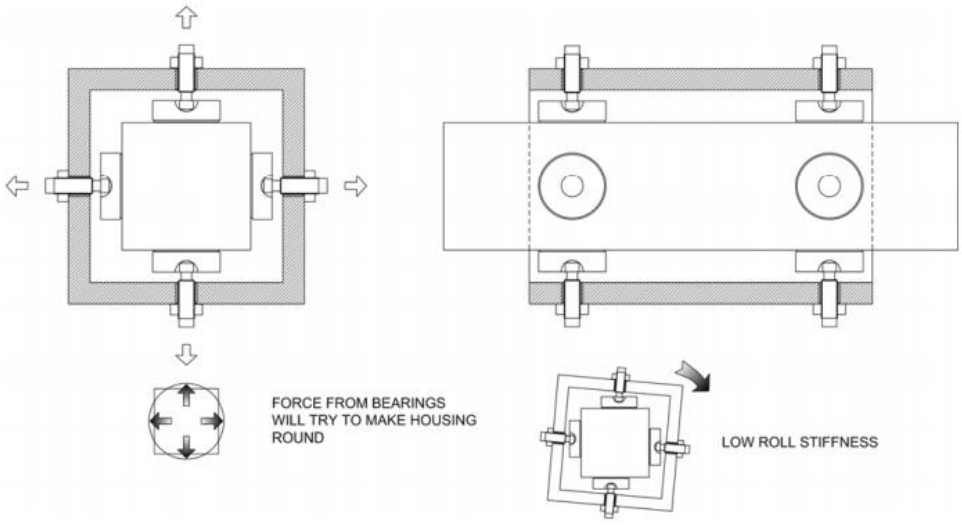

Figure 9. Linear slide with 8 flat bearings around guide way

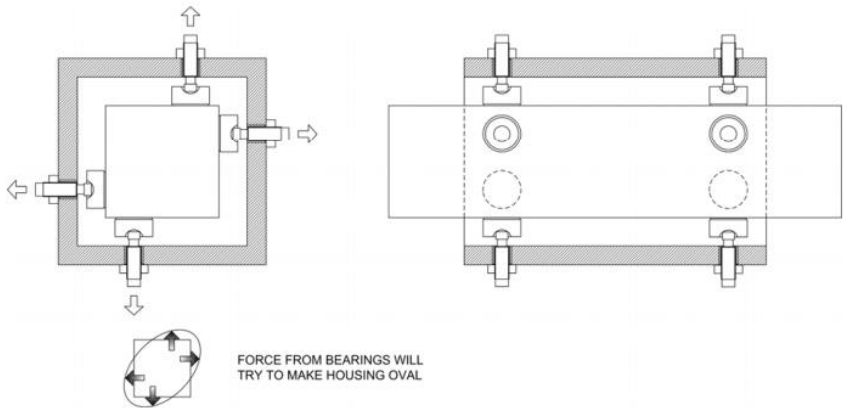

Figure 10. Linear slide with 8 flat bearings set at the corners to increase roll stiffness

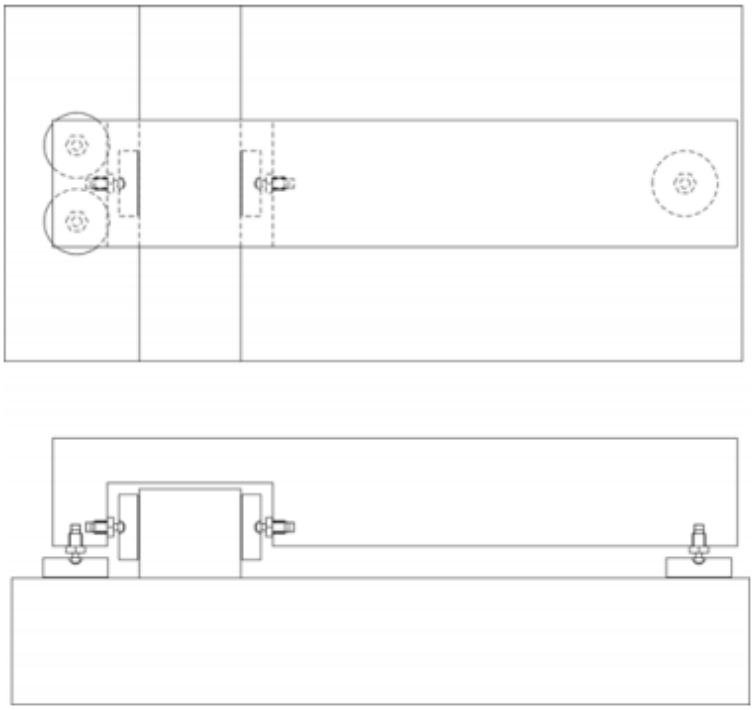

Figure 11. Stable guidance system using 5 flat air bearings

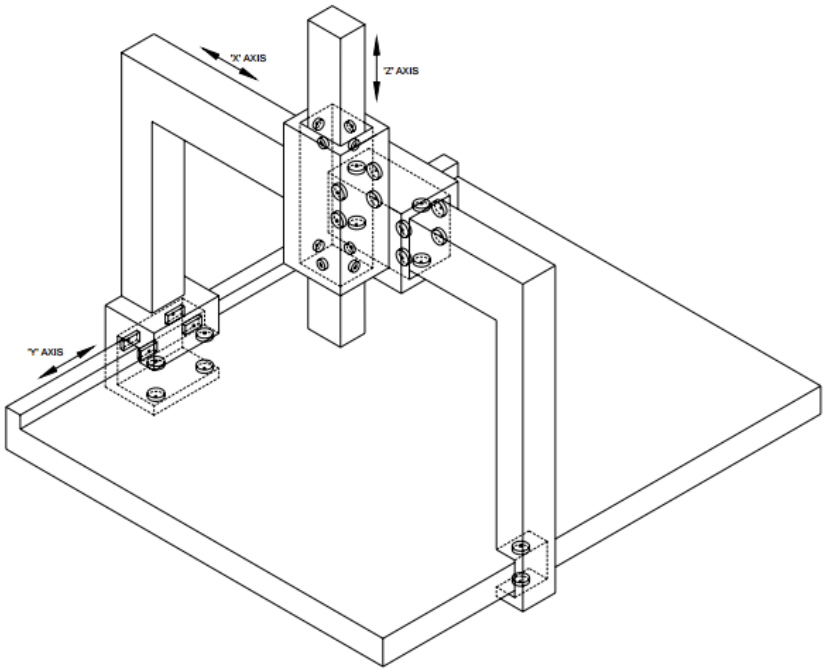

Figure 12. Typical bearing layout for CMM

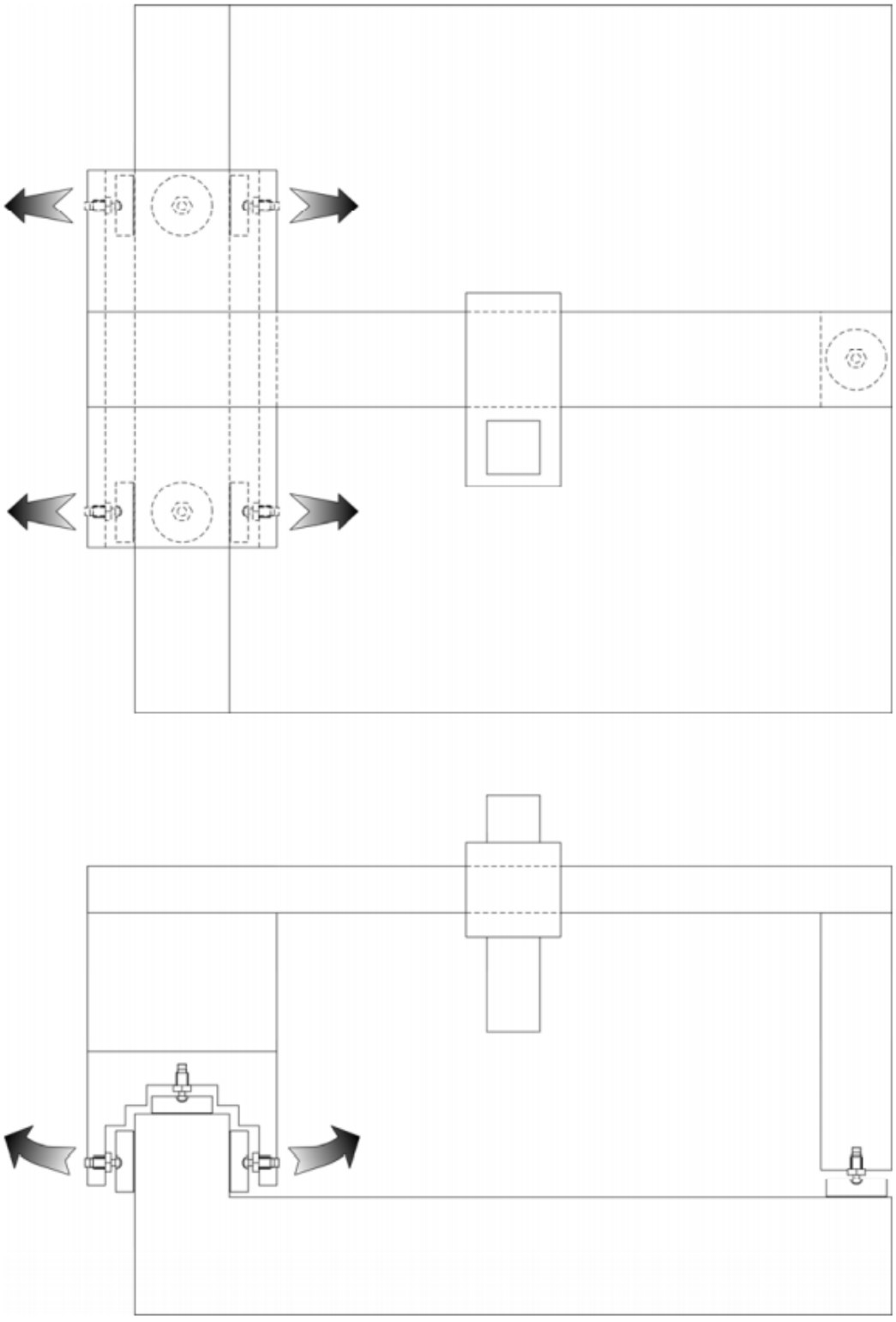

Figure 13. Stable gantry system using flat air bearings

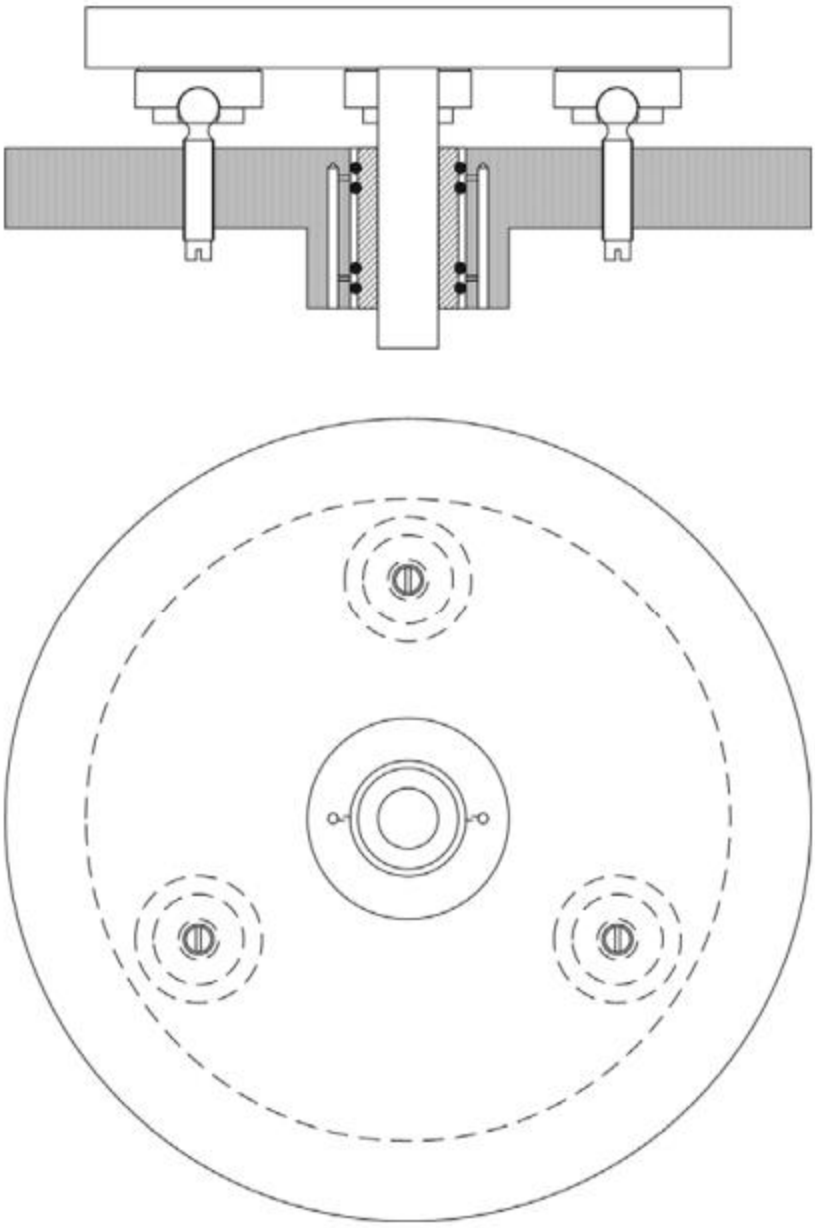

Figure 14. Rotary table using 3 flat air bearings and 1 air bushing

Air Supply

Air bearings need to be supplied with a constant source pressurized air. This air need to be relatively free of particulates, water, and oil to effectively protect and use air bearings. The table below lists the recommended requirements for air contamination.

	QUALITY CLASS	DIRT (Particle size in micron)	WATER Pressure Dew point > F (ppm. vol.) at 100psi g	OIL (including vapor mg/m^3)
	1	0.1	-94 (0.3)	0.01
	2	1	-40 (16)	0.1
RECOMMENDED	3	5	-4 (128)	1.0
MINIMUM SPECS	4	15	+37.4 (940)	5
	5	40	+44.6 (1240)	25
	6	-	+50 (1500)	-

Table 1. Air supply requirements for air bearings

References

[1] (January 2006). Air Bearing Application and Design Guide. Retrieved form http://www.newwayairbearings.com/sites/default/files/new_way_application_and_design_guide_%20Rev_E_2006-01-18.pdf

[2] Applications. Retrieved from http://www.airbearings.com/applications

[3] Model 4B BLOCK-HEAD. Retrieved from. http://www.airbearings.com/4b